BIOGENIC STRUCTURES IN THE ORDOVICIAN BOWAN PARK GROUP, NEW SOUTH WALES

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(Plates V and VI)

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Synopsis

Chondrites, large horizontal meandering burrows, small pellet-filled burrows and burrow-mottled limestones are the main biogenic structures in the Daylesford and Quondong Limestones of the Ordovician Bowan Park Group. Synsedimentary diagenetic phenomena associated with biogenic structures include obliterated primary fabrics, fragmented thin-shelled skeletons and vertically mixed sequences of sediments. The occurrence of burrows in the limestones has influenced the distribution of later alteration such as dolomitisation, grain growth, stylolitisation and silicification. The various burrows occupied consistent and unique facies during deposition of the Daylesford and Quondong Limestones : *Chondrites* occurred in dark grey lime mudstones, wackestones and packstones in intermediate to offshore environments ; large horizontal burrows and small pellet-filled burrows occurred in dark grey wackestones and packstones in intermediate environments. These burrows are comparatively rare in grainstones and grey skeletal wackestones/packstones of nearshore environments.

INTRODUCTION

Biogenic structures are common in many sedimentary rocks and there is a considerable literature dealing with their description, environmental significance and role in diagenesis (Simpson, 1957 ; Seilacher, 1964, 1967). Studies by Seilacher (1962), Farrow (1966), Goldring (1962) and others have shown their importance in unravelling ancient environments. Biogenic structures in modern sediments have been studied using plastic impregnated cores, plastic casts of burrow systems, epoxy relief peels and X-ray radiographs (Frey and Howard, 1969).

Burrows and other evidence of biogenic activity are conspicuous and important in many horizons on the Bowan Park Group (Semeniuk, 1970, 1973*b*). These biogenic structures are significant because of the associated synsedimentary diagenetic effects (particularly the mixing of facies) and because of their consistent occurrence within recurring facies in the sequence. This paper is an account of biogenic structures in the lower two formations of the group, the Daylesford and Quondong Limestones. It deals with burrow description, the role of burrowing organisms in synsedimentary diagenesis and the influence of burrows on later alteration. The occurrences of biogenic structures are placed in an inferred environmental framework of the Daylesford and Quondong Limestones.

This study is based on some 600 samples collected from five section localities (Semeniuk, 1973*a*). Samples were studied as thin sections, polished slabs and acid-etched hand specimens. Numbers prefixed by U.S.G.D. and S.U.P. refer to material catalogued in the petrology and palaeontology sections respectively of the Department of Geology, University of Sydney. Limestone classification of Dunham (1962) is used in this paper. Muddy limestone is used as a collective term for rocks with abundant lime mud, i.e. packstone, wackestone and lime mudstone.

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Outline of stratigraphy

The Ordovician Bowan Park Group (Semeniuk, 1970 ; 1973*a*) is located in the Central Fold Belt (Packham, 1969) of New South Wales, and crops out in the main limestone belt between Eurimbula and Cowra (Fig. 1). The group disconformably overlies the Cargo Andesite and is disconformably overlain by the Malachi's Hill Beds (Semeniuk, 1970 ; 1973*a*).

The Bowan Park Group consists mainly of limestone and contains three formations (Semeniuk, 1970 ; 1973*a*) :

Ballingoole Limestone (top), 280m thick ; mainly massive, generally unfossiliferous limestone ; conformably overlies *Quondong Limestone*, 34m thick ; fossiliferous, thinly bedded limestone and marl ; disconformably overlies *Daylesford Limestone*, 250m thick ; terrigenous sediment and marl in basal part, thinly bedded to massive limestone in middle part, and mainly massive limestone in upper part ; disconformably overlies Cargo Andesite.

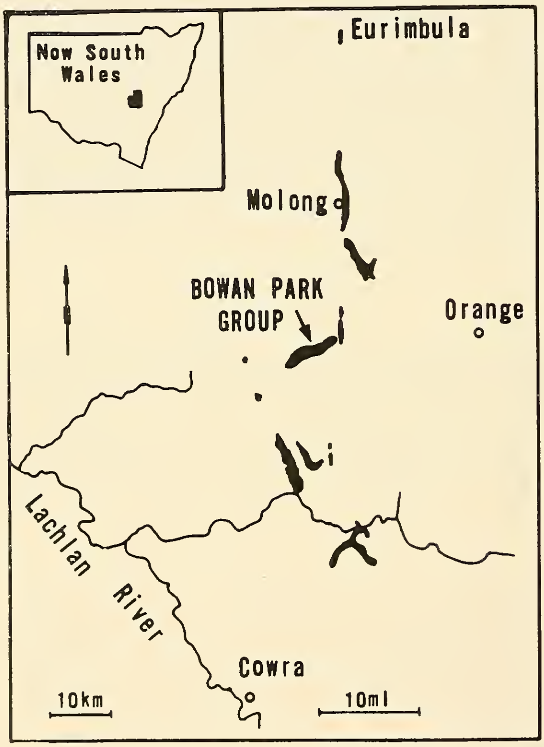

Fig. 1. Location map, distribution of Ordovician limestones between Eurimbula and Cowra and location of the Bowan Park Group.

At the type section the Daylesford Limestone contains six members, which in ascending order are : Ranch Member, Bourimbla Limestone Member, Manooka Limestone Member, Gerybong Limestone Member, Glenrae Limestone Member and Davys Plains Limestone Member. East of the type section, the Oakley Limestone Member is laterally equivalent to the Manooka and Gerybong Limestone Members. Thicknesses and diagnostic lithologies of members are summarised in Table 1.

The Quondong Limestone consists of thinly bedded grainstone, pellet packstone, skeletal wackestone and packstone and lime mudstone. Though not formally subdivided into members, the formation contains a lower part mainly of thinly bedded grainstone and pellet packstone, and an upper part mainly of marly lime mudstone and pellet packstone.

Lithofacies

The Daylesford and Quondong Limestones contain four main limestone types, and minor intercalations of terrigenous sediment. Limestones are: (1) grainstones, (2) grey skeletal wackestones and packstones, (3) dark grey burrowed wackestones and packstones and (4) dark grey burrowed lime mudstones.

Grainstones are mostly light-coloured and commonly exhibit lamination, cross-lamination and graded bedding. Gravel-sized fossils and pisolites occur in bands and platy grains are arranged parallel to lamination. Most grainstones contain well-sorted, subangular to rounded, medium to coarse sand-sized skeletal

TABLE 1
Daylesford Limestone stratigraphy

Unit	Thickness (metres)	Diagnostic Lithologies
Davys Plains Limestone Member	95	Skeletal lithoclast grainstone, skeletal wackestone and packstone, pellet packstone.
Glenrae Limestone Member	25	Light grey, vuggy and weathered limestone in upper part; intercalated and burrow-mottled grainstone, skeletal wackestone, lime mudstone in lower part.
Oakley Limestone Member	90	Skeletal grainstone. skeletal lithoclast grainstone.
Gerybong Limestone Member	64	Lime mudstone, skeletal wackestone.
Manooka Limestone Member	16	Skeletal grainstone, skeletal lithoclast grainstone, skeletal packstone and wackestone, lime mudstone.
Bourimbla Limestone Member	16	Skeletal wackestone and packstone, lime mudstone.
Ranch Member	34	Unit 3: Skeletal wackestone, lime mudstone, terrigenous mudstone. Unit 2: Skeletal grainstone, packstone and wackestone, skeletal pellet grainstone, lime mudstone. Unit 1: Lithic sandstone, terrigenous mudstone, lime mudstone.

and lithoclast grains. Grey skeletal wackestones and packstones are mostly light grey to medium grey, or, less commonly, dark grey. Burrows are uncommon. Whole gravel-sized fossils are *in situ*, in layers, or randomly oriented. Fragmented, thin-shelled skeletons are angular, poorly-sorted to well-sorted, fine sand- to gravel-sized, and comprise a minor part of the sediment.

Dark grey wackestones and packstones are commonly burrowed, containing gravel-sized and sand-sized whole and fragmented fossils in a dark grey lime mud matrix (skeletal wackestones and packstones); some sediments contain abundant pellets (pellet packstones). Large fossils are oriented in layers, or, more commonly, randomly oriented and disrupted by burrows. Sediments contain abundant poorly-sorted, angular, fine to coarse sand-sized skeletal fragments which are randomly oriented or concentrated in burrows. Skeletal fragments include thin-shelled brachiopods, sponge spicules, dasycladacean algae, ostracods, trilobites, bryozoans, small gastropods and thin-walled coral tubes.

Dark grey lime mudstones are commonly burrowed and consist of clay-sized calcite (micrite of Folk, 1965) and patches of recrystallised micrite (microspar of Folk, 1965); some contain a high proportion of silt- to fine sand-sized skeletal debris. Sand-sized angular fragments of dasycladacean algae, small gastropods, small thin-shelled brachiopods, ostracods, trilobites and sponge spicules are minor components of the sediment.

Terrigenous sediments include lithic sandstone, and brown and green mudstone. Lithic sandstones are well-laminated, medium to coarse sediments. Brown mudstones are structureless; green mudstones are burrowed, and grade into burrowed, marly lime mudstone.

Stratigraphic relationships of lithofacies

The Bowan Park Group trends approximately east-west for 9 km, and this has permitted analyses of facies changes in a direction probably perpendicular to the palaeo-shoreline (Semeniuk, 1973*b*). Grainstones and grey skeletal wackestones and packstones are more common in eastern sections of the Daylesford Limestone (as evidenced by the Oakley, Bourimbla and Ranch Members) and are laterally equivalent to dark grey lime mudstones, wackestones and packstones that dominate western sections (Semeniuk, 1973*b*). Eastern sections also contain abundant lithoclasts in grainstones; these lithoclasts are absent from the thick muddy sections to the west, except in thin horizons immediately above disconformities.

Lithofacies also tend to occur in sequential arrangement immediately above disconformities. The fully developed, idealised sequences are:

Type 1. Grainstone grading up into dark grey, burrowed, wackestone (or packstone) which grades into dark grey, burrowed lime mudstone; total average thickness 1·5 m.

Type 2. Grey skeletal wackestone and packstone (or, in marly sections, brown terrigenous mudstone) grading up into dark grey, burrowed skeletal wackestone and packstone (or green terrigenous mudstone) which grades into dark grey, burrowed lime mudstone; total average thickness 0·5 m.

These sequences are well developed above disconformities in horizons of the Quondong Limestone and in the Ranch, Manooka and Davys Plains Limestone Members of the Daylesford Limestone. Elsewhere, the sequences are only partly developed with either the basal or top lithology absent. Reversals of the sequences may occur beneath disconformities.

Description of Biogenic Structures

Five types of biogenic structures are represented in the Bowan Park Group: (1) *Chondrites*, (2) large, meandering horizontal burrows, (3) small, pellet-filled burrows, (4) burrow-mottled limestones and (5) borings.

Chondrites

The most common burrow system in the sequence is the ichnogenus *Chondrites*. Burrows are cylindrical, smooth-walled tunnels which branch laterally and regularly (Pl. V, Figs. *a*, *b*, *d*); several orders of branching are developed with tunnels radially arranged (Pl. V, Fig. *a*) and horizontal to gently inclined (Simpson, 1957). Burrow systems are spread on bed surfaces over areas up to 100 sq cm, representing a working area approximately 6 cm radius. Maximum burrow penetration, inferred from vertical slabs, is 6·5 cm; more commonly, burrow penetration is 3·0 to 4·0 cm (Pl. V, Fig. *c*). Tunnel diameter ranges from 1·5 to 3 mm but is constant in any one burrow system; rare tunnels reach

4 mm diameter. Tunnel walls are generally smooth and some are lined with a thin layer of light-coloured carbonate mud (Pl. VI, Fig. *f*), a feature which presumably represents a mucus/mud lining made to maintain burrow walls. Burrows are lined mostly when they occur in sandy host sediments such as packstones and grainstones.

Burrows are filled with sediment, usually lighter in colour than the host sediment. The fill commonly exhibits a concentric lamination in transverse section (Pl. VI, Figs. *a*, *c*) and downward draping of laminae in longitudinal sections. There is no increase in pellet content within burrows as compared with outside, but some burrows contain a high proportion of fragmented skeletal material (Pl. VI, Fig. *e*). Burrows may penetrate lithologically distinct laminae and are filled by sediment similar to the upper layer (Pl. VI, Fig. *c*). Some tunnels are only partly filled with sediment and the remaining void contains sparry calcite cement. Burrows totally filled by sparry calcite are rare. Most of the Bowan Park *Chondrites* appear to have been filled early since filled tunnels are reworked by as many as four later burrows (Pl. VI, Fig. *b*). Although most contemporaneous burrows do not intersect because of some chemical control which prevented the animal from working sediment that already had been exploited, later burrows may intersect earlier ones (Simpson, 1957).

Chondrites occurs in dark grey lime mudstone and dark grey wackestone and packstone that are present in most units of the Daylesford and Quondong Limestones, and in green terrigenous mudstone of Unit 1 of the Ranch Member.

Horizontal meandering burrows

Large meandering burrows that occasionally bifurcate (Pl. V, Fig. *h*), are second in abundance in the sequence. As many as 30 burrows have been found on a square metre of bedding. Burrows are circular in cross section (1 cm diameter) and tend to follow bedding planes, with some extending over distances of 1m. Numerous vertical pipes (1 cm diameter) connect the horizontal tunnels (Pl. V, Fig. *g*).

Tunnels may be partially to completely filled by sandy or silty mud, with sparry calcite filling any remaining pore space (Pl. V, Fig. *f*) ; some tunnels are lined with carbonate mud forming a smooth wall. Most burrow-fills, however, are partly to completely replaced by a coarse dolomite mosaic (Pl. V, Fig. *g*) ; the burrow/host sediment contact may also be obliterated. In some, dolomite has advanced beyond the original burrow resulting in vague, cylindrical, interconnected patches of dolomite mosaic.

Large meandering burrows occur in dark grey skeletal wackestone of Bourimbla, Manooka and Gerybong Limestone Members, in burrowed pellet packstone and skeletal wackestone that occur in the transitional facies between Gerybong Limestone Member and Oakley Limestone Member and also in burrowed pellet packstone at the contact of Quondong and Ballingoole Limestones.

Pellet-filled burrows

Small pellet-filled burrows are circular in cross section (1 mm diameter) and consist of meandering and branching tubes up to 3 cm long. Some are lined with carbonate mud. Burrows are filled partly or completely with faecal pellets (Pl. VI, Fig. *a*) ; sparry calcite fills any void space. These burrows are best developed in dark grey wackestones of the Manooka Limestone Member where they are abundant between the pillars of the receptaculitid *Ischadites* (Semeniuk and Byrnes, 1971). Here the burrows consist of randomly oriented tubes. Small pellet-filled burrows also occur in dark grey skeletal wackestones in Unit 2 of the Ranch Member.

Burrow-mottled limestones

Burrow-mottled limestones are those sediments so thoroughly reworked by burrowers that both the original fabric and the burrow form have been largely destroyed. The limestones vary from homogeneous wackestones and packstones to sediments with patches of grainstone, packstone, wackestone and lime mudstone. Cross sections of small to large burrows are evident in vertical slabs and thin sections but, apart from *Chondrites*, the geometry of most burrows cannot be determined since they have been obliterated by later biogenic activity.

Burrow-mottled limestones occur in some horizons of Manooka Limestone Member, in the transitional facies between Gerybong Limestone Member and Oakley Limestone Member (Fig. 2) and in the Davys Plains Limestone Member.

Borings

Borings are cylindrical holes (generally 2 to 4 mm in diameter) that truncate rock fabrics and sparry calcite mosaics (Pl. VI, Fig. *g*) and indicate tunnelling into cemented sediment. They are commonly filled by contemporary marine sand or later sparry calcite. Borings also occur in brachiopods (Pl. VI, Fig. *h*) and corals ; these holes are generally small (0·4 to 0·6 mm diameter) but may reach 5 mm diameter, particularly in corals.

Borings have been found only in grainstones of Manooka and Davys Plains Limestone Members of the Daylesford Limestone, and also in limestones of the Quondong Limestone ; where they penetrate rock fabrics they illustrate hard ground conditions were present. Borings, however, are rare in the sequence and will not be discussed further here.

Role of Burrowing Organisms in Synsedimentary Diagenesis

Burrowing organisms have affected sediments of the Bowan Park sequence in the following ways : (1) by vertically mixing sequences of facies, (2) by obliterating original fabric and lamination and disorienting large oriented grains within facies and (3) by fragmenting skeletal material.

Vertical mixing of facies

The ability of burrowers to mix a vertical sequence of sediments has important geological implications as the resulting sediment may be a mixture of two or more facies (Logan *et al.*, 1969). Where grain types are facies-restricted and where end-member sediment-types have been found elsewhere within the sequence in a partly mixed or unmixed section, it is possible to ascertain how many lithofacies have been mixed. The problem is easily resolved where one sediment occurs as patches in another.

Burrowing organisms in the Bowan Park sequence have been responsible for mixing of sediments. Detailed studies of some sections have provided comparisons of unmixed, partially mixed, and thoroughly mixed sequences. Sections in Unit 2 of the Ranch Member have illustrated partial mixing. Biogenic reworking has not been intense but infiltration of overlying sediment into burrows has produced a patchy distribution of sediment-types within the beds (Pl. VI, Fig. *c*). In the Manooka Limestone Member, burrowing has been more intense and burrowing organisms have mixed sections which originally consisted of interbedded grainstone, packstone, wackestone and lime mudstone. At the west end of one horizon near the base of the Manooka Limestone Member, for example, grainstone/muddy limestone intercalations were mixed by burrowing organisms to produce a 3 m-thick relatively homogenous burrow-mottled grainstone/packstone bed within a predominantly lime mudstone/skeletal wackestone sequence. Burrowing is less intense 4 km to the east and patches of individual

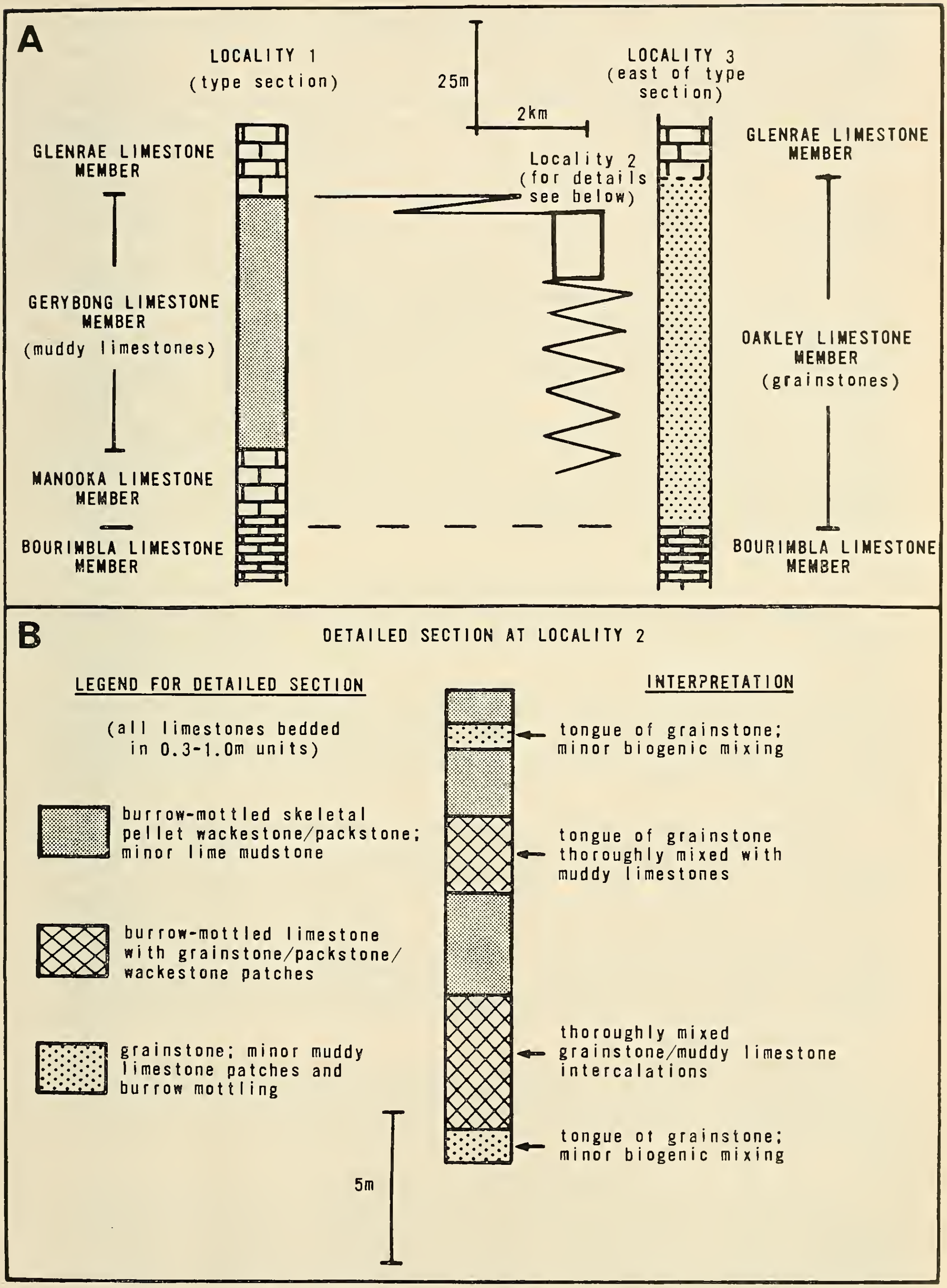

Fig. 2. A. Generalised diagram showing facies relationships between Oakley Limestone and Gerybong Limestone Members. B. Detail at locality 2 of transitional sequence between Oakley Limestone and Gerybong Limestone Members; section illustrates biogenic mixing of interbedded grainstones and muddy limestones.

sediments types are recognisable : the horizon consists of muddy limestone-filled burrows and grainstone-filled burrows within a mottled grainstone to packstone host-sediment. Finally, at the east end of outcrops, only massive grainstone occurs and no burrows are evident.

Similar mixing occurs at localities where burrowed muddy sediments of the Gerybong Limestone Member interfinger with and pass laterally into grainstones of the Oakley Limestone Member (Fig. 2). The transitional section consists mainly of thickly bedded, intercalated grainstone, skeletal pellet wackestone and packstone, pallet packstone, lime mudstone and burrow-mottled mixtures of these sediments. Vertical contacts between sediment types are commonly burrowed.

The results outlined above have been used in the interpretation of environments of the Davys Plains Limestone Member (Semeniuk, 1973*b*). Sediments in the member include grainstone and dark grey muddy limestones. Although unburrowed sediments such as laminated and cross laminated grainstone are recognisable in many horizons, portions of the member consisting of interbedded grainstone/muddy limestone appear to have been mixed by burrowing organisms that kept pace with sedimentation. Burrowing organisms have produced, locally, a burrow-mottled to relatively homogeneous packstone or wackestone where pisolites and rounded sand grains (which are both diagnostic of grainstone lithofacies) occur in a muddy matrix (Pl. VI, Fig. *d*) ; more commonly, burrowing organisms have produced a mottled limestone in which patches of grainstone and muddy limestone are still discernible.

Obliteration of original fabric

Biogenic activity disrupts primary laminations and other sedimentary structures and ultimately destroys all original fabric (Ginsburg, 1957). In muddy sediments of the Bowan Park sequence, patches of original sediment are observed where burrowing has not been intense. There are two primary fabrics : (1) massive, unlaminated lime mudstone with scattered fossils or (2) skeletal wackestone and packstone with laminae of silt-, sand-, or gravel-sized skeletal debris. Intense burrowing obliterates original fabrics and produces a mottled fabric in which circular to cylindrical outlines of filled tunnels are dominant (Pl. V, Fig. *e*).

Burrows also disrupt oriented larger grains from original bedding positions to form fabrics in which most grains are randomly oriented. For instance, the large brachiopod *Eodinobolus* occurs beak down in growth position or as disarticulated valves oriented convex-up or convex-down in some unburrowed horizons of the Bourimbla Limestone Member. Where burrows occur, articulated and disarticulated valves are found in random orientations. Reorientation of grains is striking where encrusting coralline organisms are present. Coralline organisms would have encrusted only upper portions of shell gravel layers but disruption of the fabric by burrowers has resulted in random orientations of both shells and encrustations.

Burrows generally are uncommon in grainstones, which are bedded with lamination, cross-lamination and graded-bedding. Burrows in these sediments truncate sedimentary structures to varying degrees depending on the intensity of biogenic activity.

Fragmentation of skeletal material

Burrowing organisms can modify grain size (Dapples, 1938 ; Rhoads, 1967). Feeding, ingestion or the mechanical act of excavating tunnels can comminute skeletal material, particularly if skeletons are fragile. Intense burrowing can produce a sediment composed of angular, highly fragmented shells, explaining how skeletons are highly fragmented in quiet-water environments (Matthews, 1966). In the Bowan Park sequence, weakly burrowed horizons may contain articulated and disarticulated complete valves of thin-shelled brachiopods, together with recognisable sponge spicules, dasycladacean algae, trilobites, ostracods and coral tubes. As burrows become more numerous, thin-shelled skeletons become fragmented and form angular, skeletal sand and silt, which is common in many dark grey burrowed lime mudstones, wackestones and packstones (Pl. VI, Figs. *b*, *e*).

Influence of Burrows on Later Alteration

Biogenic structures have influenced distribution of some late (diagenetic or low-grade burial metamorphic) alteration phenomena such as dolomitisation, grain growth, silicification and stylolitisation. In addition to undergoing normal diagenesis, limestones of the Bowan Park Group have been subjected to low-temperature burial metamorphism of the prehnite-pumpellyite-metagreywacke facies of Coombs (1960), as evidenced by alteration in the overlying rocks of the Malachi's Hill Beds (Semeniuk, 1970). It has been difficult, however, to differentiate late diagenetic alteration from that produced by burial metamorphism.

Apart from some dolomite associated with faults, stylolites and chert nodules, most dolomite in the sequence is associated with large burrows (Pl. VI, Fig. *g*) and, to a less extent, *Chondrites* burrows. This dolomite commonly connects with thin sheet-like dolomite mosaics that are localised along cracks and stylolites. Dolomite appears to have replaced predominantly burrow-fill sediment, forming a coarse interlocking mosaic with calcite patches in inter-rhomb areas. Dolomitised burrows grade into undolomitised and partly dolomitised burrows; within these latter burrows, burrow-fills commonly are sandier than the enclosing host sediment, suggesting selective dolomitisation of burrow-fills may have been related to the higher porosity of material in burrows relative to the surrounding host sediment.

Many burrow-fill sediments also exhibit grain growth mosaics, especially if there is a contrast in character between burrow-fill material and host sediment. Grain growth is most pronounced where burrows in lime mudstone are filled with grainstone. Sparry calcite cement of the grainstone is recrystallised to the extent that it is poikiloblastic. Wackestone and mudstone filled burrows in a lime mudstone host are recrystallised to a mosaic of microspar (Folk, 1965) while the surrounding host undergoes comparably little or no recrystallisation. This results in burrow-fills which are granular, and lighter-coloured in thin section. Where lime mudstone, wackestone or packstone fills a burrow in grainstone, similar grain growth phenomena occur but mosaics are ragged at the burrow periphery.

Less important alteration phenomena associated with burrows include silicification, where portions of dolomitised burrows are silicified, and stylolitisation, where the stylolites follow the physical discontinuity at the burrow/host rock contact.

Occurrence of Burrows Within Inferred Depositional Environments

In the Daylesford Limestone, the convergence of disconformities to the east, the dominance of grainstones and grey skeletal wackestones and packstones in eastern sections and the occurrence of lithoclasts in the thick grainstone sequences all suggest a positive area to the east of the depositional basin (Semeniuk, 1973*b*). Grainstones and grey skeletal wackestones and packstones probably bordered the positive area as fringing deposits. Dark grey burrowed muddy limestones occurred in the subsiding area to the west. The convergence of disconformities to the east and similar suites of lithologies within the Quondong Limestone suggest a similar palaeogeographic and environmental setting for this formation.

The lateral facies changes also are reflected (immediately above disconformities) in the vertical sequences which probably were deposited under transgressive conditions and relate to deepening water. The sequences generally indicate increased effects of burrowing, increased accumulation of mud relative to grains, decreasing energy, and relatively increased reducing conditions.

Grainstones commonly form the base of Type 1 transgressive sequences (p. 132). Grey skeletal wackestones and packstones (or brown terrigenous mudstones) form the base of Type 2 transgressive sequences (p. 132). This stratigraphic position and relationship to the positive area suggests the grainstones and grey skeletal wackestones and packstones are nearshore, shallow water sediments. In marly sequences, brown terrigenous mudstones substituted for grey skeletal wackestones and packstones.

Dark grey burrowed lime mudstones occur at the top of most transgressive successions and predominate in western localities. Abundance of lime mud and lack of shallow water indicators suggest the sediments formed under low energy conditions, probably beneath wave base. These sediments are interpreted as offshore deposits.

Stratigraphically the dark grey burrowed wackestones and packstones generally occur above grainstones (or grey skeletal packstones and wackestones) and below dark grey lime mudstone. The sediments are interpreted as having formed in intermediate depths of water. In marly sequences, green terrigenous mudstones substituted for dark grey wackestones and packstones.

The various burrows occurred in consistent facies throughout deposition of the Daylesford and Quondong Limestones. For instance, *Chondrites* burrows always occur in abundance within dark grey lime mudstones, wackestones and packstones that are interpreted as offshore to intermediate facies, and which are present in all phases of sedimentation of these formations. Bathymetry, rather than sediment type, appears to have controlled their distribution : *Chondrites* burrows are uncommon in all shallow water sediments, e.g. in grey skeletal wackestones and packstones of the Bourimbla Limestone Member and the Quondong Limestone and in grainstones of the Quondong Limestone and Manooka, Oakley and Davys Plains Limestone Members of the Daylesford Limestone. *Chondrites* distribution within reconstructed depositional environments of Ranch, Bourimbla, Manooka, Gerybong and Oakley Limestone Members is illustrated in Fig. 3.

Horizontal meandering burrows occur predominantly in dark grey skeletal wackestones and packstones, sediments interpreted to have formed in intermediate depths of water. The burrows overlap the distribution of *Chondrites*. Their position relative to *Chondrites* is consistent during four depositional phases of the Daylesford Limestone (Fig. 3). Small pellet-filled burrows appear in two units of the Daylesford Limestone ; both appearances occur in dark grey skeletal wackestone interpreted as sediments formed at intermediate depths (Fig. 3).

The occurrences of biogenic structures in these unique environmental positions aid environmental interpretation of some vertically or laterally incomplete sections. Where they occur, burrows can be used to infer relative bathymetry. For instance, *Chondrites*-burrowed lime mudstones may be placed as the deepest facies and other sediment types treated as shallow water equivalents. Biogenic structures are used to complement information given by other criteria and there is good correlation between environments suggested by burrows and that suggested by petrographic and palaeontologic data.

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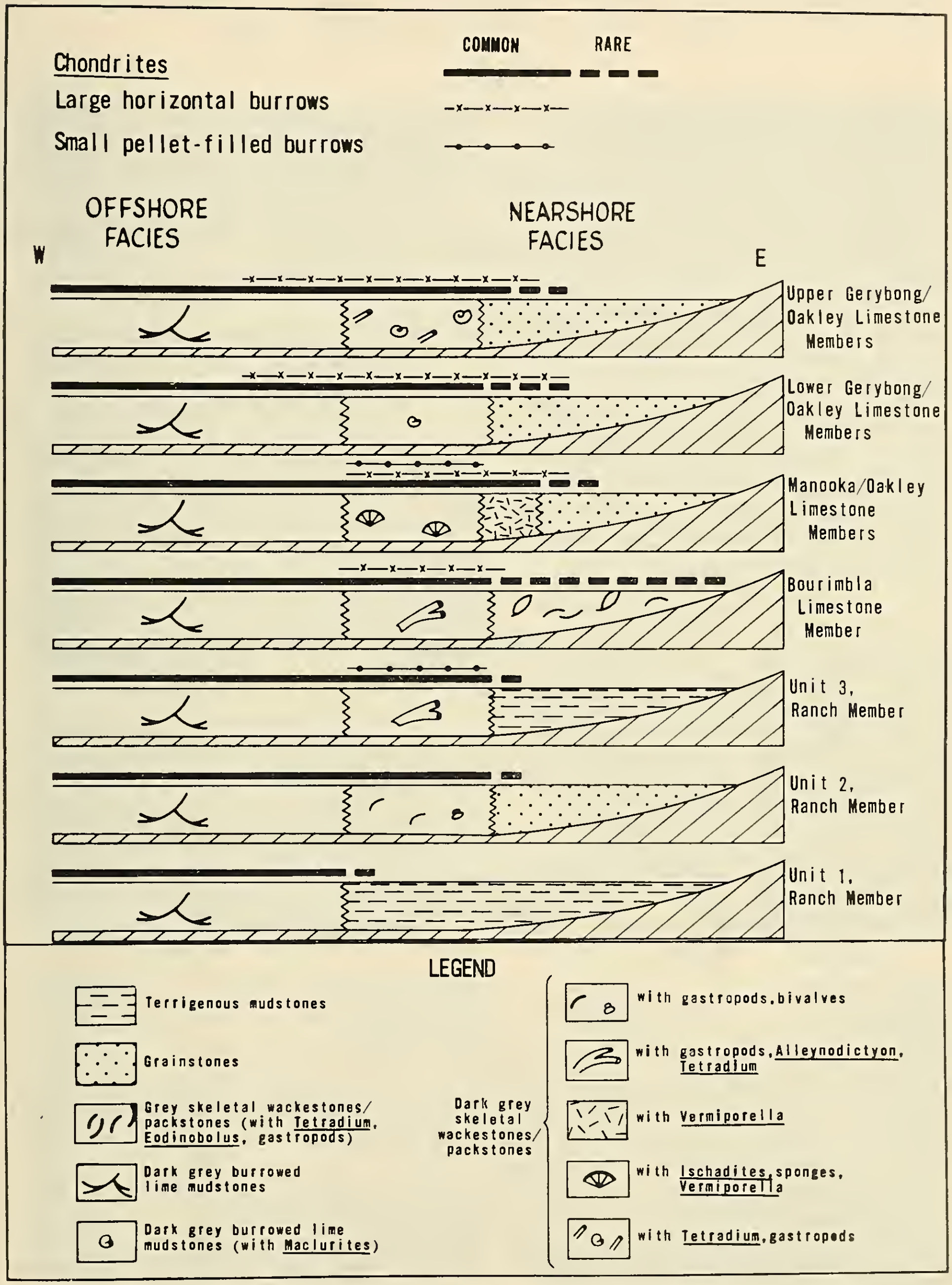

Fig. 3. Distribution of burrow types within reconstructed facies during various phases of sedimentation of lower to middle Daylesford Limestone. (*Alleynodictyon* = cylindrical stromatoporoid; *Eodinobolus* = inarticulate brachiopod; *Ischadites* = receptaculitid; *Vermiporella* = dasycladacean alga).

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EXPLANATION OF PLATES

Plate V

Fig. *a*. *Chrondites* burrows showing radial arrangement of tunnels on bedding plane surface of limestone. Upper Bourimbla Limestone Member of Daylesford Limestone, S.U.P. 23859.

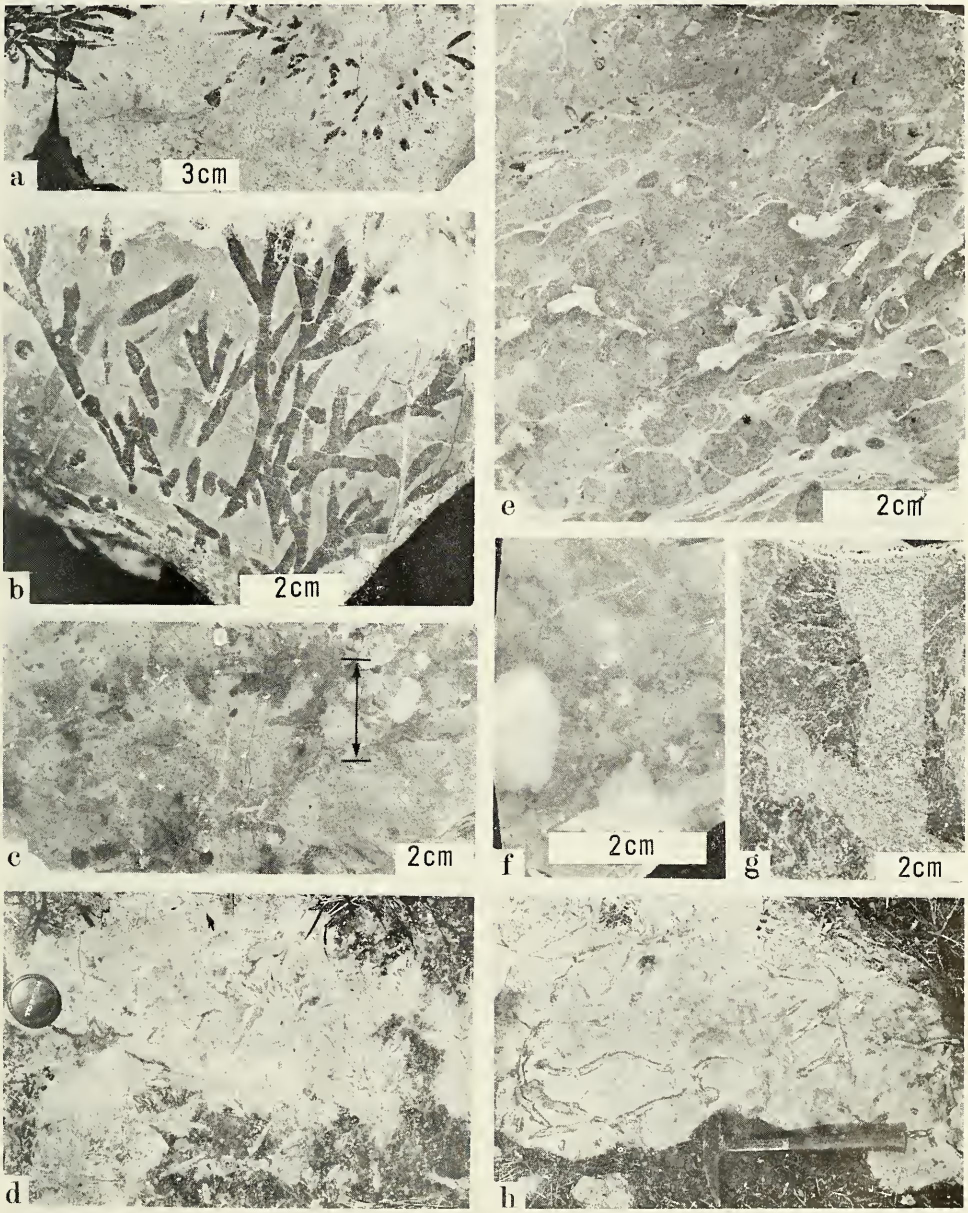
Fig. *b*. *Chondrites* burrows showing branching pattern of tunnels on bedding plane surface of limestone. Quondong Limestone, S.U.P. 23860.

Fig. *c*. Vertically oriented slab showing depth of penetration (arrowed) of *Chondrites* burrows. Bourimbla Limestone Member of Daylesford Limestone, U.S.G.D. 42195.

Fig. *d*. *Chondrites* burrows and large horizontal burrows on bedding plane surface of limestone of upper Gerybong Limestone Member near " Quondong " property. Lens cap diameter approximately 5 cm.

Fig. *e*. Burrow-mottled fabric produced by intense bioturbation. Ranch Member of Daylesford Limestone, U.S.G.D. 46676, polished slab.

Fig. *f*. Vertical slab of (undolomitised) large horizontal burrow (left of photo) showing sediment partly filling tunnel and sparry calcite filling remaining void space ; surrounding limestone is burrow-mottled. Glenrae Limestone Member of Daylesford Limestone, U.S.G.D. 46737.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